

Express Mail Label No. EL 738 149 561 US

Date of Mailing MARCH 30, 2001

PATENT
Case No. DP-304354
(7500/51)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
APPLICATION FOR UNITED STATES LETTERS PATENT

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TITLE: FIBER OPTIC CALIBRATION FIXTURE
AND METHOD

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DP-304354

FIBER OPTIC CALIBRATION FIXTURE AND METHOD

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TECHNICAL FIELD

The present invention is related to instrumented fasteners. In particular, the present invention is related to a fixture and method for calibrating instrumented fasteners.

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BACKGROUND OF THE INVENTION

The use of threaded fasteners to connect materials together is well known. As used herein, threaded fasteners include nuts and bolts, bolts received in tapped holes, studs, and the like. The fasteners and the elements that are fastened together are collectively termed a joint.

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Compression of the joint and the tension along the shank of the threaded fastener affect the quality of the joint. When assessing joint properties, fastener creep and other joint-specific qualities, it is necessary to ascertain joint strain or clamp-load. However, fastener tension is difficult to measure directly. Typically, fastener tension has been deduced from measurements of fastener torque, because this measurement is easily taken during assembly of the joint. However, the relationship between fastener torque and tension is dependent on a number of variables including the coefficient of friction between the fastener and the elements to be connected. Even identical fasteners can produce significantly different joint loads when driven to same torque levels. Instead of relying on torque or the like, load washers, certain ultrasonic techniques and instrumented bolts have all been used to provide more direct indications of fastener tension.

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The uses of fiber optic sensors are also well known in the art, which are useful for detecting vibration, pressure, strain and other forces. When used in conjunction with a fastener, the combination of the fiber optic sensor and the fastener is referred to as an instrumented fastener. The instrumentation uses fiber optic technology to determine the amount of strain, and hence clamp load in a joint. This information is useful when evaluating fastener performance and joint performance in different assembled systems, for example.

In order for this instrumentation to provide consistent data, each fastener including instrumentation should be accurately calibrated.

SUMMARY OF THE INVENTION

One aspect of the present invention provides a fixture for calibrating an instrumented fastener including an upper member. A cap member can be removably attached to the upper member. The cap member can include an opening formed therein to receive an upper portion of the fastener. A lower member can be positioned adjacent the cap member, the lower member including an opening formed therein. A removable insert can be positioned in the lower member opening to receive a lower portion of the fastener.

Other aspects of the present invention provide a cap that includes a joint specific spacer section to provide a predetermined position of the fastener within the fixture. The upper member can include a threaded extension for threaded attachment to the cap member. The upper member can include a chamber formed therein for receiving the upper portion of the fastener. The upper member can further include a port formed therein, the port allowing cable access to the upper member chamber. The cap member opening can be a threaded opening, or and unthreaded opening. The lower member opening can be a threaded opening. The lower member can further include a chamber formed

therein. The lower member can further include a port formed therein, the port allowing cable access to the lower member chamber. The removable insert can include a threaded outer portion for threaded engagement with the lower member opening. The removable insert can include a threaded opening, the threaded opening including a configuration adapted to threadably engage the lower portion of the fastener. The removable insert can be one of a plurality of removable inserts, each of which including a threaded opening adapted to threadably engage a fastener with a different engaging configuration.

10 The upper member and the cap member can comprise an upper section. The lower member and the removable insert can comprise a lower section. The upper section and the lower section can each include an attachment portion.

15 Another aspect of the present invention provides a method of calibrating an instrumented fastener including positioning a fiber-optic sensor within a fastener. A removable insert member is positioned within a lower member of a calibration fixture. A cap member is positioned adjacent to the removable insert member. The fastener is inserted through an opening in the cap member. A lower threaded portion of the fastener is screwed into the threaded insert member. The cap member is attached to an upper section of the calibration fixture. The fiber optic sensor is operably connected to a measuring device. A predetermined tensile force is applied to the fastener and recording a measurement from the fiber-optic sensor.

20 Other aspects of the method of the present invention provide a predetermined tensile force being applied to the fastener by applying a tensile force to the upper and lower members of the calibration fixture.

Another aspect of the present invention provides a system for calibrating an instrumented fastener including a means for positioning a fiber-optic sensor within a fastener, a means for positioning a removable insert member within a lower section of a calibration fixture, means for positioning a cap member adjacent to the removable insert member, means for inserting the fastener through the cap member, means for securing a lower threaded portion of the fastener within the threaded insert member, means for attaching the cap member to an upper section of the calibration fixture, means for operably connecting the fiber-optic sensor to a measuring device, means for applying a predetermined tensile force to the fastener and means for recording a measurement from the fiber-optic sensor.

The foregoing and other features and advantages of the invention will become further apparent from the following detailed description of the presently preferred embodiments, read in conjunction with the accompanying drawings. The detailed description and drawings are merely illustrative of the invention rather than limiting, the scope of the invention being defined by the appended claims and equivalents thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of an embodiment of the fixture of the present invention; and

FIG. 2 is an illustration of another embodiment of the system of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to **FIG. 1**, one embodiment of the calibration fixture of the present invention is shown generally at **10**. The fixture for calibration of a fastener or other coupling device including a strain gauge or fiber-optic instrument generally comprises a lower section **12**, a threaded insert **14**, an end cap **16** and an upper section **18**.

In the embodiment shown in **FIG. 1**, the lower section **12** and the insert **14** can be fastened together. The end cap **16** and the upper section **18** can be fastened together. When positioned adjacent each other the lower assembly **12, 14** and the upper assembly **16, 18** define a joint therebetween. An instrumented fastener can be provided, which holds the lower assembly **12, 14** to the upper assembly **16, 18**.

As will be described and shown more fully herein, a predetermined tensile force is applied to the upper and lower assemblies **16, 18; 12, 14** (by, for example, a testing device manufactured by Instron Corporation, and shown generally at **FIG. 2**). The tensile force stretches the fastener (not shown) across the joint **19**. An instrument in the fastener detects the amount of strain in the fastener and an associated processor assigns a value corresponding to the amount of strain detected by the. The instrument can be, for example, a fiber-optic sensor. The value represents the amount of strain in the fastener at the predetermined tensile force.

The lower member or section **12** of the fixture **10** can include a lower extending portion **20**. The lower extending portion **20** can include a lower attachment hole **22**, which, as shown in the illustrated embodiment, can be a perpendicular hole formed through the lower extending portion **20**. The lower section **12** can include a lower port **24** for cable access therethrough, or the like. The lower port **24** can be an opening in the body of the lower section **12** that can exit at an end **26** or a sidewall **28**, for example, of the lower section **12**. The lower port **24** can communicate with an inner chamber **30**. The inner chamber **30** can be formed as an axial chamber, which communicates with the lower port **24** at a first end **32**, and can include a threaded portion **34** at a second end thereof.

A threaded insert **14** can be removably attachable to the threaded portion **34** of the lower section **12**. The insert **14** can be provided with outer threads **38** to engage the threaded portion **34** of the lower section **12**. Each insert **14** designed for different fasteners can be provided a same outer thread pitch, for example, a 1:14 external thread pitch for engagement with the threaded portion **34** and consistent calibration results. An internal threaded bore **40** can be formed in the threaded insert **14**. It will be understood that the configuration or specifications of the internal threaded bore **40** will be fastener specific. In other words, the diameter and thread pitch of the bore **40** will be formed according to the specifications of the fastener to be calibrated. Thus, the specifications of the inner diameter **42** of the bore of the internal thread **40** will differ when calibrating a fastener with a major diameter of 8 mm as compared to a 6 mm fastener, or a fastener having 14 threads per inch (TPI) compared to a fastener having 16 TPI. The bore **40** can be open at both ends so that a fastener (not shown) can be inserted therethrough. The insert **14** can be designed to receive an entire or a portion of the threaded length of the intended fastener. From the figure, it can be seen that the insert **14** can thread into the lower section **12** such that a flat surface (at **19**) can be provided.

The end cap **16** contacts the flat surface provided by the lower section **12** and insert **14** to define joint **19**. The end cap **16** includes an opening **44** with a first diameter **42** to receive a portion of the length of the fastener, and a second diameter **46** to receive the head portion of the fastener, in the event that the fastener is a screw or bolt. If a stud, or like coupler, is being calibrated, the opening **44** may be threaded. However, when calibrating fasteners with some length having no threads formed thereon, (i.e., a portion of the length of the fastener adjacent the head) the opening **44** may be unthreaded.

The thickness **48** of the end cap **16** can be provided at a specified or predetermined thickness. The specified thickness can be made equal to the thickness of the element that will be held by the fastener when the fastener is applied to the joint to be tested. For example, if a one-inch plate is to be fastened to a block by a fastener calibrated by the present invention, the predetermined thickness **48** of the cap **16** can be specified at one inch. Whereas some fasteners may be calibrated only by reproducing the configuration of the joint precisely, some fasteners may be accurately calibrated using configurations that are not exact duplications of the joint dimensions.

The second diameter of the opening **46** can be provided with threads to permit a threaded connection between the end cap **16** and a threaded extension **50** of the upper section **18**. The upper section **18** can include a chamber **52**, which can extend axially. An upper port **54** can be formed through the upper section **18** to allow a cable or the like to pass from the chamber **52** and out of the upper section **18**. An extension **56** can be provided with an opening **58** to permit attachment of the upper section or member **18** to an external device.

Referring to **FIG. 2**, another embodiment of present invention is illustrated generally at **100**. A fastener **160** to be calibrated is shown in phantom. It should be understood that the fastener **160** to be calibrated could be a bolt, screw, stud, rod, or the like. A strain gauge **162**, which can be a fiber-optic sensor, can be positioned in the fastener **160**.

A fixture **110** can include an upper assembly, or section **164**, and a lower assembly or section **166**. The lower assembly **166** can include a threaded insert member **114** that is secured within a lower member **112** of the fixture to hold the fastener **160** at a lower portion **168**. A cup member **116** that is secured to an upper member **118** of the fixture **110** can be positioned to hold an upper portion **170** of the fastener **160**, which in this case, is the head of a bolt, or the like. An opening **172** in the cup member **116** can receive the head of the bolt, the opening **172** forming a chamber with an opening **152** in the upper member **118**. An upper port **154** and a lower port **124** can be formed in the upper member **118** and the lower member **112** respectively to permit a cable **174**, or the like, to exit the fixture **110** and connect in an operative fashion to a processor **176**.

The upper and lower members **118**, **112** can include a fastener portion or attachment portion **156**, **120**. It will be understood that the configuration of the attachment portions **156**, **120** will be adapted to secure the fixture **110** to a force-applying device **178** designed to apply a tensile force to the fixture **110**. Thus, the force-applying device **178** will include upper and lower clamps **180**, **182**, or the like, which attach to the attachment portions **156**, **120** in a secure fashion. Since the tensile forces to be applied to the instrumented fastener **160** can be quite high it will be understood that the fixture **160**, attachment portions **156**, **120**, clamps **180**, **182** and force-applying device **178** will be of a robust nature.

In one embodiment, as is known in the art, a signal is sent through the cable **174** and can reflect off of a surface or portion of the sensor **162** positioned within the fastener **160**. The signal can reflect off of the sensor surface, and returns to the processor **176**. The time it takes for the signal to travel through of the cable **174**, reflect off the sensor surface and return to the processor corresponds to the distance the signal must travel. As the fastener **160** is stretched during application of the tensile force thereto the signal takes a longer time to travel to and return from the surface. A correspondingly different value is assigned to the longer time interval.

In operation, to prepare the instrumented fastener **160**, a fiber-optic sensor **162** is positioned and secured within a fastener. In one embodiment, the sensor **162** can be secured within the fastener **160** by using epoxy. The sensor **162** can include an end mirror surface that reflects light.

The assembly of the fixture **110** can begin by positioning the removable insert member **114** within a lower member **112** of the calibration fixture. A cap member **116** can be positioned adjacent to the removable insert member **114**. The fastener **160** including the sensor **162** can be inserted through an opening **144** in the cap member **116**, and screwed into a threaded portion or bore of the insert member **114**. An upper section **118** of the calibration fixture **110** can be attached to the cap member **116**. The fiber-optic sensor **162** can be operably connected to a measuring device **176**. As discussed previously, the device can be a processor, which generates a signal and measures the time interval the signal travels. The predetermined tensile force is applied to the fastener **160**. The processor **176** records the signal from the sensor **162**.

The processor **176** can assign a value to the recorded signal, which in one embodiment is a voltage. For example, if a tensioned instrumented fastener **160** generates a two volt signal when tensioned at 20 Kilonewtons (kN) in the calibration fixture **110**, it will be understood that when the same fastener is used in a joint to be tested, or the like, that the two volt signal generated by the fastener **160** will correspond to a clamping force in the joint of 20 kN.

5 With each different fastener **160** to be calibrated in this manner, only a new threaded insert member **114** and, in some instances, a cap member **116** need to be manufactured. Accordingly, consistent calibration of different fasteners is ensured.

10 While the embodiment of the invention disclosed herein is presently considered to be preferred, various changes and modifications can be made without departing from the spirit and scope of the invention. The scope of the invention is indicated in the appended claims, and all changes that come within the meaning and range of equivalents are intended to be embraced therein.